Climate Change in the Nile Basin

Implications for water and agricultural management

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April 26, 2018

Introduction: Why care about climate change?

"Pricetag" of climate change:

1. Changing rainfall patterns:
   - Mean flow of the Nile
   - Inter-annual variability in water
2. Increased temperatures:
   - Higher irrigation water demand
   - Potential decline of agricultural yields
3. Sea-level rise:
   - Loss of agricultural land in the Nile Delta
   - Displacement of population

$\boxed{\rightarrow \text{Discuss implications on water use / sharing in the basin!}}$

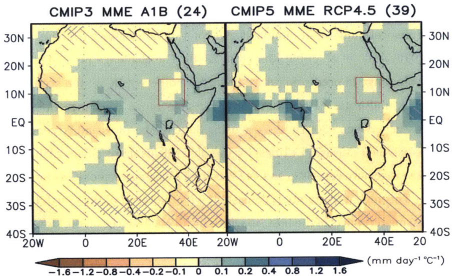
Overview

1. Future of water resources in the basin
2. Temperature change, agricultural yields and cropping patterns
3. The Nile Delta and sea-level rise
4. Adapting to change

1. Future of water resources in the basin

General considerations

- Most of the flow originates in Ethiopia, so we must focus on this region
- Potential impact on White Nile attenuated by Sudd swamps
- Up until recently, change in rainfall was unclear: conflicting model projections, no physical basis
- Recent work shed new light on physical forcings, helping select best models



Multimodel June-September rainfall change for Africa, 2080-2099 vs. 1986-2005 [*Siam 2016*]

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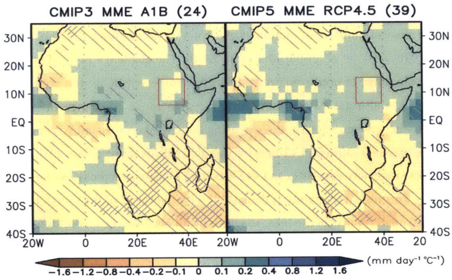


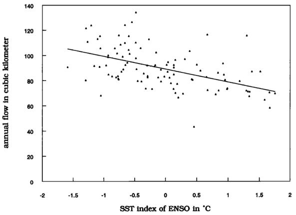
Multimodel June-September rainfall change for Africa, 2080-2099 vs. 1986-2005 [*Siam 2016*]

→ Climate change picture is now much clearer:

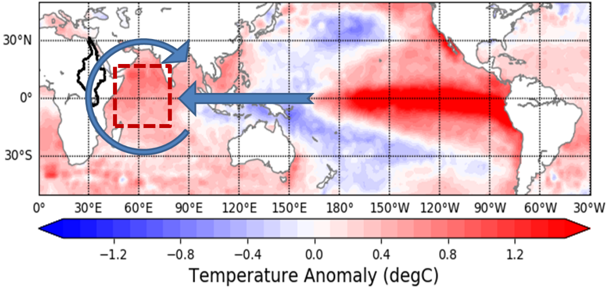
$\boxed{\text{More water... but with more variability}}$

What drives interannual variability?

- Regional climate is **naturally variable**, with high year-to-year changes in rainfall and Nile flow
- Main source of variability comes from ENSO phenomenon, recently explained [*Siam et al. 2016*]
- Natural oscillating pattern of Pacific Ocean temperatures, with large-scale climate repercussions

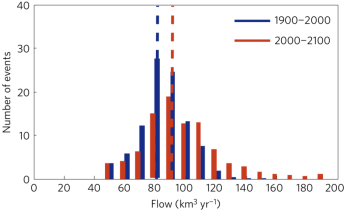


ENSO Index and annual Nile flow [*Eltahir 1996*]



ENSO's future and its consequences for the Nile

- In-depth study using most recent climate models predicting **strong increase in ENSO variability**, with theoretical, observational and modelling arguments [*Cai et al. 2014, 2015*]
- More floods and more droughts



Histograms of past (blue) and future (red) annual flows

nature climate change | LETTERS
PUBLISHED ONLINE: 19 JANUARY 2014 | DOI: 10.1038/NCLIMATE2100

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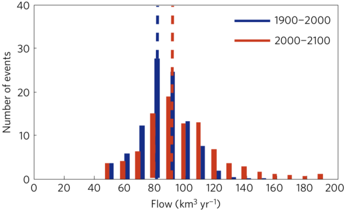

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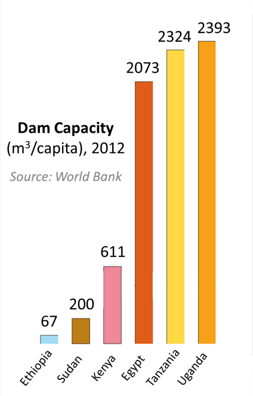
Climate change enhances interannual variability of the Nile river flow

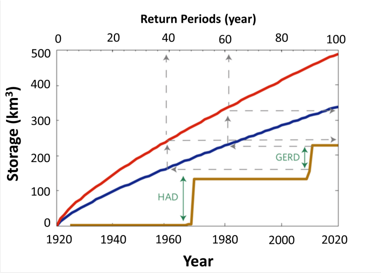
$\boxed{\rightarrow \text{Increased inter-annual variability of Nile flow}}$

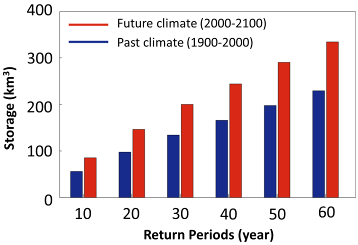
also consistent with direct GCM projections for Upper Blue Nile basin

How much more storage?

- Significant changes in return periods: today's storage = 60 years (current climate) = 40 years (future climate)
- Reequilibrate storage between countries?

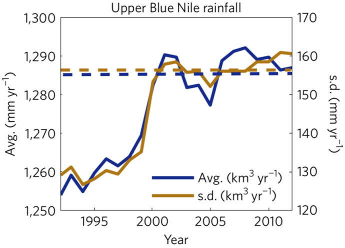


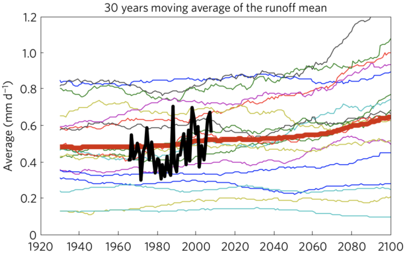




What about mean flow?

- Past studies have **contradicted one another** on the sign of rainfall/runoff change in UBN:
- Difficulty: a 10% change in precipitation translates into a 25% or greater change in runoff
- But **careful model selection** shows a slight (10%) increase in mean annual flow [*Siam 2017*]
- Projections for mean flow and variability are **consistent** with observed upward trends over past decades

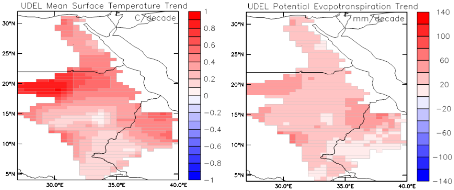




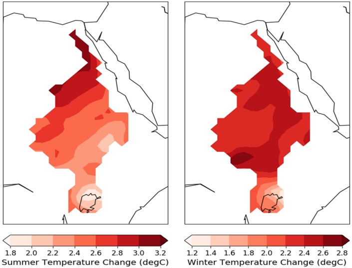
2. Temperature change, agricultural yields and cropping patterns

Temperatures are rising already... and will keep going up!

- Significant upward trends in mean and extreme temperatures over the last decades
- Temperatures expected to rise by 3-6°C by 2100
- Impacts on agricultural yield, cropping patterns, water demand
- Evaporation from Aswan could increase by 1.5-3km^3



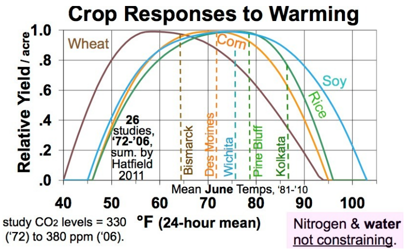
Observed trends (1980-2009), UDEL

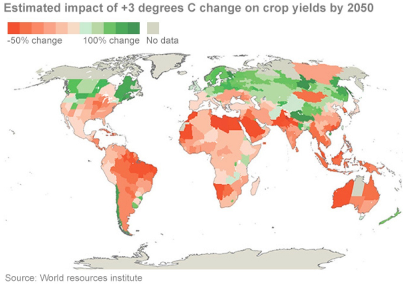


Projected change in mean temperature for 2070-2100 (summer and winter), CMIP5 RCP 85 multimodel mean

Crop yield and temperatures

- Optimal crop growth not only dependent on water + inputs, but also temperatures
- Substantial evidence that most crops follow a bell-curve "yield vs. average temperature"
- Potential reduction in yields in Nile Basin due to temperature increase, pushing to the right of optimal
- Additionally: occasional heatwaves may devastate fields





Crop suitability areas

Different types of crops require different environmental conditions (water, temperature): Climate change will impact where crops can be grown!

Substantial shifts predicted in agricultural patterns, even with lower emissions scenario:

<table>
<tr><th>Ethiopia</th><th>Egypt</th><th>Sudan</th></tr>
<tr><td colspan="3">Significant reduction in suitable area for staples (rice, wheat, maize)</td></tr>
<tr><td>All months remain suitable for cropping</td><td colspan="2">Summer crops more difficult</td></tr>
<tr><td colspan="2">More suitable for "warm" crops</td><td>Overall reduction in suitable land</td></tr>
<tr><td>Rainfall variability: perennial crops</td><td colspan="2">Shift toward shorter-duration crops</td></tr>
</table>

3. The Nile Delta and sea-level rise

A vital agricultural region...

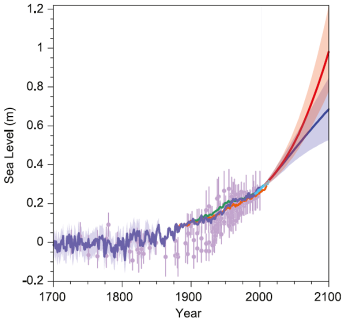
- 2.5% of Egypt's area
- $>$ 30% of its population
- 30-40% of agricultural production
- Largest irrigated area in Africa (1.7 million ha)

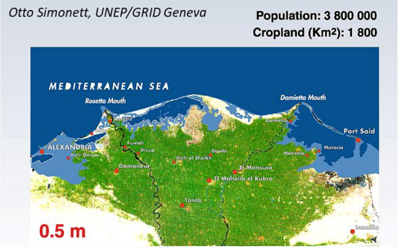
But...

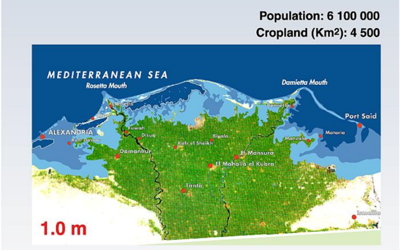
- Most of the delta is less than 5m above sea-level
- Already subsiding at 3-5mm/yr

… that will be damaged by climate change

- Sea-level rising everywhere, faster in the Eastern Mediterranean
- Low-end projection ≥ 50cm by 2100, at least 4 million people displaced
- Up to 18% of existing cropland could be lost
- Sea-water intrusion + salinisation: difficult agriculture management!







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6. Fertile agricultural lands in Egypt severely threatened

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   → Where should what be grown under future water/temperature constraints?

Integrating water and climate scenarios

Things to think about...

- Whole basin is affected, but each country differently, strengthening differences
- Population growth/technological uncertainty add to uncertainty
- Coordinating reservoirs for climate change mitigation
- Strengthening intra-basin agricultural trade can help adapt to new agricultural constraints
- Long-term reflexion on economic development: benefit- or water-sharing?

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→ Building **resiliency** of the system

→ Allowing **long-term flexibility** in agreement

Conclusion

1. Climate change brings opportunity for **more water**, but at the price of impacting where and how crops are grown (Nile Delta, suitability zones)

2. **Water security** under a changing climate will be even less achievable within a single country's borders: basin-wide **cooperation and negociation** is the only option!